The Procedures described in this presentation are available in the following KDB publications:

- KDB 941225:
  - SAR Measurement Procedures for 3G Devices
    - CDMA 2000 / Ev-Do
    - WCDMA / HSDPA
- KDB 865664:
  - SAR Measurement Requirements for 3 – 6 GHz
- KDB 248227:
  - SAR Measurement Procedures for 802.11 a/b/g Transmitters

Agenda

- SAR Measurement Procedures for 3G Devices
  - CDMA 2000 / Ev-Do
  - WCDMA / HSDPA
- SAR Measurement Requirements for 3 – 6 GHz
- SAR Measurement Procedures for 802.11 a/b/g Transmitters

- SAR Measurement Procedures -

for

3G Devices

CDMA 2000 / EV-DO

WCDMA / HSDPA

(Released June 2006)

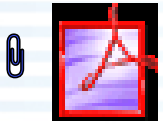
Overview

- SAR measurement procedures for 3G devices
  - Part 22 & Part 24 handsets and data modems
  - procedures may not fully apply to other radio services
- test configurations are mostly derived according to
  - 3GPP2/TIA & 3GPP standards
- devices are tested according to
  - operating capabilities and dominant use conditions
- device test configurations are standardized
  - for head & body SAR measurements
  - to minimize SAR variations

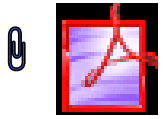
CDMA 2000

- procedures for Release 0 & Release A handsets with
  - MS Protocol Revision 6 & 7
    - 1x RTT only or
    - 1x RTT and built-in Ev-Do
- head/body SAR is measured in RC3
  - with established radio link through call processing
  - using the same RC in forward and reverse links
- SAR in RC1 is selectively confirmed
  - according to output power and exposure conditions


Uplink Channel Structure

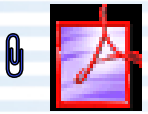

Channel Configuration


Radio Configurations


Service Options

Output Power

- verify maximum output power
  - on high, middle and low channels
  - according to 3GPP2 C.S0011 / TIA-98-E, Sec. 4.4.5
  - to determine SAR test configurations
- power measurement configurations
  - Test Mode 1, SO55, RC1, Traffic Channel @ 9600 bps
  - Test Mode 3, SO55 or SO32, RC3, FCH @ 9600 bps
  - Test Mode 3, SO32, RC3, FCH+SCH @ 9600 bps
  - other configurations supported by the DUT
  - power control
    - Bits Hold for FCH+SCH
    - otherwise All Bits Up


Output Power


FCH-SCH Power Control


FCH+SCH Output

Head SAR

- measure in RC3
  - at full rate with Loopback SO55
  - according to applicable requirements
    - in Supplement C 01-01 & IEEE 1528
- measure in RC1 on the maximum output channel
  - **only** if maximum average output ≥ ¼ dB higher than RC3
  - use the exposure configuration that result in the highest SAR for that channel in RC3
    - highest SAR configuration among left & right side, touch & tilt positions with antenna extended and retracted

Body SAR

- measure in RC3 at full rate using TDSO SO32 with
  - FCH only (may use SO55 instead of SO32)
  - FCH + SCH (must use TDSO SO32)
    - **only** if the maximum average output power ≥ ¼ dB higher than with FCH only
    - use the exposure configuration that result in the highest SAR for that channel with FCH only
    - monitor output fluctuations and SCH dropout
- measure in RC1
  - **only** if the maximum average output power ≥ ¼ dB higher than RC3 FCH only & FCH + SCH
  - use the body exposure configuration that result in the highest SAR, with antenna extended and retracted, for that channel in RC3

Ev-Do

- Procedures for Rev. 0 & Rev. A (IS-856 / TIA-856-A)
  - Ev-Do & 1x RTT may roam but not simultaneously active
- measure SAR
  - with established radio link through call processing
  - or use chipset based Factory Test Mode (FTM) with communication test set and no call processing
- configure DUT according to
  - FTAP/RTAP (C.S0029-0) and Subtype 0/1 PHY configurations
  - FETAP/RETAP (C.S0029-A) and Subtype 2 PHY configurations
  - maximum output power procedures in C.S0033
- SAR in 1x RTT & Ev-Do Rev. A are selectively confirmed
  - according to output power and exposure conditions


Channel Configuration


Uplink Channel Structure


Downlink Coding


Uplink Coding

Output Power

- configure measurements according to
  - C.S0033-0 / TIA-866 for Rev. 0
    - FTAP: 2 slot version of 307.2 kbps; ACK in all slots
    - RTAP: 153.6 kbps in Subtype 0/1 PHY configuration
  - C.S0033-A for Rev. A
    - FETAP: 2 slot version of 307.2 kbps with ACK in all slots
    - RETAP: 4096 bits payload with 16 slot termination target in Subtype 2 PHY configuration
- power control
  - 'All Bits Up' in both FTM & call processing modes

Head & Body SAR

- body SAR
  - is required for Rev. 0 in Subtype 0/1 PHY configuration
  - is **NOT** required for Rev. A when the maximum average output power in Subtype 2 PHY configuration is less than in Subtype 0/1
    - otherwise, measure SAR on the maximum output channel using the exposure configuration that result in the highest SAR for that channel in Rev. 0
- head SAR is **NOT** required unless
  - device supports VOIP for operations next to ear

Ev-Do & 1x RTT

- 1x RTT SAR is **NOT** required for Ev-Do devices
  - when the maximum average output power for 1x RTT < ¼ dB higher than Subtype 0/1
    - otherwise, measure body SAR with CDMA 2000 procedures
- SAR is **NOT** required for handsets with built-in Ev-Do
  - when the maximum average output power for Ev-Do Rev. 0 < ¼ dB higher than 1x RTT in RC3
    - otherwise test SAR in Subtype 0/1 PHY configuration on the maximum output channel using the exposure configuration that result in the highest SAR for that channel in RC3
  - when the maximum average output power for Ev-Do Rev. A < Rev. 0 or < ¼ dB higher than 1x RTT RC3
    - otherwise test SAR in Subtype 2 PHY configuration on the maximum output channel using the exposure configuration that result in the highest SAR for that channel

WCDMA

- procedures for Release 99 & Release 5 handsets with
  - WCDMA only
  - WCDMA and built-in HSDPA
- head and body SAR is measured with
  - established radio link through call processing
  - 12.3 kbps RMC and Test Loop Mode 1
- SAR is selectively confirmed for other physical channel configurations (DPCCH & $DPDCH_n$)
  - according to output power, exposure conditions and device operating capabilities


Channel Structure


Channelization Code


AMR


UE Options

Output Power

- verify maximum output power
  - on high, middle and low channels
  - according to 3GPP TS 34.121, Sec. 5.2
  - using appropriate RMC or AMC with TPC set to all "1's"
- power measurement configurations
  - 12.2 kbps RMC and 12.2 kbps AMC
  - other configurations supported by the DUT
    - 64, 144, 384, 768 kbps RMC
    - $DPDCH_{2 \ldots 6}$ when applicable

12.2 RMC

Head SAR

- measured in 12.2 kbps RMC
  - according to applicable requirements
    - in Supplement C 01-01 & IEEE 1528
- SAR is **NOT** required for AMC
  - when the maximum average output power for 12.2 kbps AMC < ¼ dB higher than 12.2 kbps RMC
  - otherwise, measure SAR on the maximum output channel in 12.2 kbps AMC with a 3.4 kbps SRB
    - use the exposure configuration that result in the highest SAR for that channel in 12.2 kbps RMC
      - highest SAR configuration among left & right side, touch & tilt positions with antenna extended and retracted

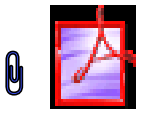
Body SAR

- measured in 12.2 kbps RMC
- SAR is **NOT** required for other spreading codes and multiple $DPDCH_n$ supported by the device
  - when the maximum output for each of these other configurations < ¼ dB higher than 12.2 kbps RMC
  - otherwise, measure SAR on the maximum output channel in each of these configurations
    - use the body exposure configuration that result in the highest SAR, with antenna extended and retracted, for that channel in 12.2 kbps RMC

HSDPA

- procedures for Release 5
  - HSDPA is an integral part of WCDMA
  - HSDPA & WCDMA are simultaneously active
- measured SAR
  - with established radio link through call processing
  - or chipset based Factory Test Mode (FTM) with communication test set and no call processing
  - in WCDMA with 12.2 kbps RMC and Test Loop Mode 1
  - in HSDPA with FRC and 12.2 kbps RMC using the highest SAR configuration in WCDMA
- SAR is selectively confirmed for other physical channel configurations (DPCCH & $DPDCH_n$)
  - according to output power, exposure conditions and device operating capabilities


HSDPA


H-Set 1

Output Power

- verify maximum output power
  - on high, middle and low channels
  - according to 3GPP TS 34.121, Release 5, Sec. 5.2
  - using appropriate FRC and RMC with TPC set to all "1's"
- measurement configurations
  - 12.2 kbps RMC
  - 12.2 kbps FRC with 12.2 kbps RMC
- other configurations supported by the DUT
  - DPCCH, $DPDCH_n$, spreading codes, HS-DPCCH etc.

Head & Body SAR

- when voice transmission and head exposure conditions are applicable
  - use WCDMA handset head SAR procedures
- body exposure for HSPDA data devices
  - use WCDMA handset body SAR procedures, and
  - FRC with a 12.2 kbps RMC in Test Loop Mode 1
    - using the highest body SAR configuration in 12.2 kbps RMC without HSDPA

RFC & H-Sets

- H-set is configured in FRC according to UE category
  - HS-DSCH/HS-PDSCHs, HARQ processes, minimum inter-TTI interval, transport block sizes, RV coding sequence are defined by H-set
- use QPSK in H-set
- use CQI feedback cycle of 2 ms in HS-DPCCH
- use β_c=9 and β_d=15 for DPCCH and DPDCH gain factors
- use $\Delta_{ACK} = \Delta_{NACK}$=5 and Δ_{CQI}=2

- SAR Measurement Requirements -

for

3 – 6 GHz

(Released October 2006)

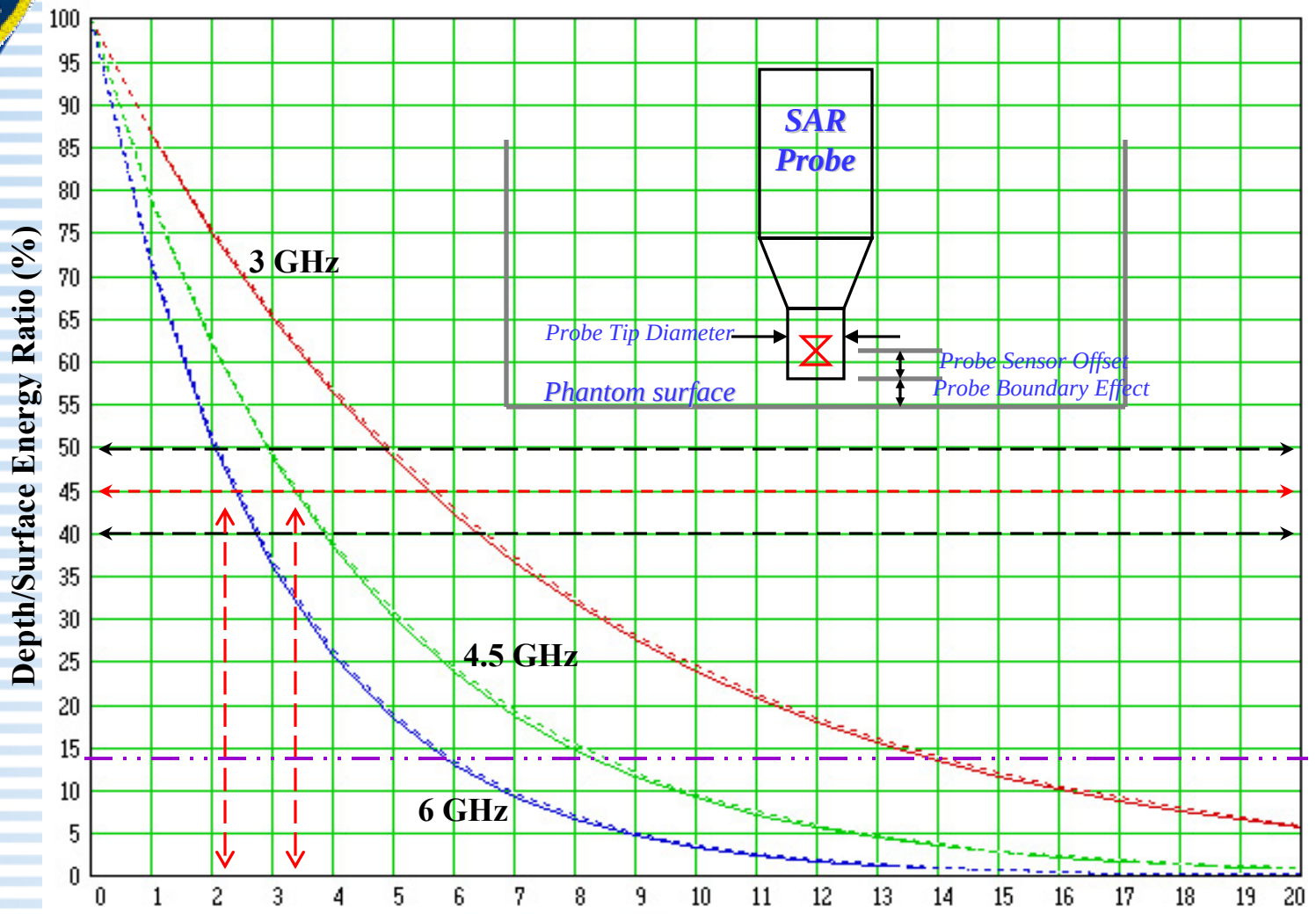
Overview

- identify SAR measurement and instrumentation issues
  - smaller penetration depth at higher frequencies
  - higher field gradients closer to the tissue boundary
  - existing SAR procedures for below 3 GHz are insufficient
  - tissue-equivalent media recipes require non-polar liquids
- review of FCC exploratory measurements and standards committees discussions
- provide interim guidance for equipment certification
- enable an acceptable level of measurement confidence while standards are being developed

Phantom

- head and flat phantom
  - according to Supplement C 01-01 & IEEE 1528 criteria
  - phantom shell issues under investigation by IEEE / IEC
    - need to account for underestimated SAR
- ±10% ε_r & ±5% σ for liquid target value uncertainty
- dielectric measurement uncertainty remains at ± 5%
- 10 cm liquid depth from SAM ERP or flat phantom
- flat phantom size
  - 5 cm surrounding transmitter
  - or 3 penetration depths around measurement region
  - maximum of 2 overlapping area scans to cover entire projections of certain standalone fully integrated DUT
  - regions of host device not contributing to SAR may extending beyond phantom margin

Measurement Constraints



Probe Requirements

< 4.5 GHz	Frequency	≥ 4.5 GHz
≤ 4 mm	Probe Tip Diameter	≤ 3 mm
≤ 2 mm	Probe Sensor Offset	≤ 1.5 mm
$\varepsilon_r \leq \pm 10\%, \sigma \leq \pm 5\%$ < 15%, k=2	± 50 MHz > Probe Calibration ≤ ± 100 MHz Calibration Uncertainty	$\varepsilon_r \leq \pm 10\%, \sigma \leq \pm 5\%$ < 15%, k=2
$\varepsilon_r \leq \pm 5\%, \sigma \leq \pm 2.5\%$ < 20%	Probe Calibration Range > ± 100 MHz Calibration Uncertainty (Submit Certification to FCC)	$\varepsilon_r \leq \pm 5\%, \sigma \leq \pm 2.5\%$ < 20%

SAR Scan Requirements

< 4.5 GHz	Frequency	≥ 4.5 GHz
≤ 3.5 ±0.5 mm	Closest Measurement Point to Phantom	≤ 2.5 ±0.5 mm
≤ 5 mm	Zoom Scan (x, y) Resolution	≤ 4 mm
≤ 3 mm	Zoom Scan (z) Resolution	≤ 2.5 mm
≥ 30 x 30 x 24	Minimum Zoom Scan Volume	≥ 24 x 24 x 20
≥ 7 x 7 x 9	Minimum Zoom Scan Grid Points	≥ 7 x 7 x 9

SAR Scan Procedures

- probe boundary effect compensation required when
  - probe tip to phantom surface distance < ½ probe tip diameter
  - or probe boundary effects error > 5%
- area scan resolution ≤ 10 mm
- peaks in area scan > 1.0 cm from scan boundary
- zoom scan configurations
  - 1st two measurement points ≤ 5 mm of phantom surface
    - 3 points recommended above 4.5 GHz
  - when graded grids (z) are used
    - 1st point < 3 mm to phantom surface at < 4.5 GHz
    - 1st point < 2.0 mm to phantom surface at ≥ 4.5 GHz
    - subsequent graded grid ratio < 2.0; 1.5 recommended
  - 1-g SAR volume ≥ 5 mm from zoom scan boundary

Post- Processing

- post-processing algorithm accuracy
  - equivalent to 5 mm area scan measurement resolution
  - equivalent to 1 mm zoom scan measurement resolution
- verify with IEC 62209-2 SAR Reference Functions
  - 3 available functions to cover different SAR distributions
  - different area/zoom scan resolutions require independent verification
- verify interpolated/extrapolated peak SAR to identify post-processing errors
  - in highest SAR configuration
  - according to measured and extrapolated (curve-fitted) values

System Accuracy

- verify SAR measurement system accuracy
  - according to Supplement C 01-01 & IEEE 1528 criteria
  - using IEC 62209-2 (IEEE 1528a) reference dipoles
  - must measure within a valid probe calibration range
- system accuracy tolerance
  - 1-g SAR within 10% of manufacturer calibrated dipole target value
  - extrapolated peak SAR at phantom surface above dipole feed-point within 15% of calibrated target peak SAR of dipole

System Verification

- higher frequencies are mostly broadband
  - reference dipoles may not be available at desired frequencies
- SAR systems may be verified
  - within device transmission band or within ± 100 MHz of device mid-band frequency
  - within ± 200 MHz of device mid-band frequency only if both system verification and DUT are measured
    - using the same tissue-equivalent medium
    - the same probe calibration point, area/zoom scan resolutions, interpolation and extrapolation procedures

Duty Factor vs. Crest Factor

For t = pulse width and T = period of a pulse train

Duty factor of a periodic pulse train is t/T

Crest factor (voltage) of a periodic pulse train is $\frac{1}{\sqrt{\frac{t}{T}}}$

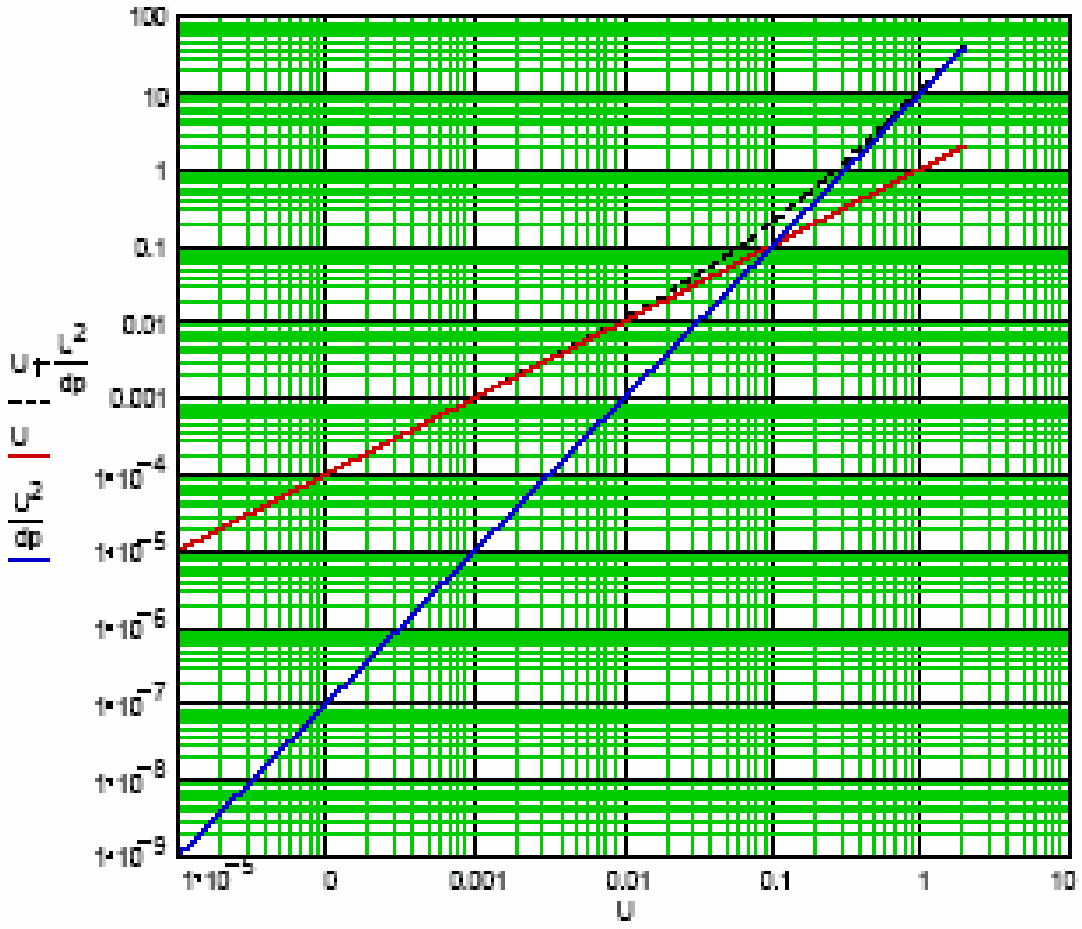
Power $\propto$ voltage^2; therefore, peak to average power ratio is T/t

For TDMA with 2/6 duty factor, $cf = 3$;

GSM with 1/8 duty factor, $cf = 8$

Signal Conversion

- **SAR field-probe signal conversion equation in typical systems:**



$$V_i = U_i + U_i^2 \frac{cf}{dcp_i}$$

- U_i is the measured voltage
- $V_i \propto$ power
- cf is $\propto$ power
- dcp_i is the diode compression voltage

$$E_i = \sqrt{\frac{V_i}{Norm_i * ConvF}}$$

- $E_i \propto$ E-field

- SAR Measurement Procedures -

for

802.11 a/b/g Transmitters

(Released October 2006)

Overview

- 802.11 a/b/g in §§15.247, 15.407 and Part 90Y
- dynamic network operating configurations & conditions result in unreliable test environment
- test mode conditions may not evaluate normal exposure
- multiple data rates, modulation schemes, operating protocols (a/b/g), antenna diversity and other proprietary configurations require substantial test considerations
- SAR measurement difficulties relating to voltage crest factors and peak to average power ratios of random noise-like signals

SAR Evaluation

- measure SAR according to
  - Supplement C 01-01 and IEEE 1528 criteria
  - October 06 release: “3 – 6 GHz SAR Measurement Requirements”
- configure the DUT in chipset based Factory Test Mode
- test the required channels, proprietary modes and antenna diversity configurations
- report both measured and duty factor adjusted SAR
- verify voltage crest factor and peak to average power ratio issues before SAR measurements and apply modified procedures as necessary

Modulation & Data Rate

802.11 a/g OFDM, 802.11g DSSS-OFDM, 4.9 GHz half/quarter-clocked				802.11b/g	
Data Rate (Mbps)			Modulation	Data Rate (Mbps)	Modulation
full	half	quarter			
6	3	1.5	BPSK	1	DBPSK
9	4.5	2.25	BPSK	2	DQPSK
12	6	3	QPSK	5.5	CCK / PBCC
18	9	4.5	QPSK	11	CCK / PBCC
24	12	6	16-QAM	22	ERP-PBCC
36	18	9	16-QAM	33	ERP-PBCC
48	24	12	64-QAM		
54	27	13.5	64-QAM		

Part 15 Test Channels

Mode		GHz	Channel	Turbo Channel	"Default Test Channels" §15.247 802.11b	§15.247 802.11g	UNII	
802.11 b/g		2.412	1		√	∇		
		2.437	6	6	√	∇		
		2.462	11		√	∇		
802.11 a	UNII	5.18	36				√	
		5.20	40	42 (5.21 GHz)				*
		5.22	44					*
		5.24	48	50 (5.25 GHz)			√	
		5.26	52				√	
		5.28	56	58 (5.29 GHz)				*
		5.30	60					*
		5.32	64				√	
		5.500	100	Unknown				*
		5.520	104				√	
		5.540	108					*
		5.560	112					*
		5.580	116				√	
		5.600	120					*
		5.620	124				√	
		5.640	128					*
		5.660	132					*
		5.680	136				√	
		5.700	140					*
	UNII or §15.247	5.745	149		√		√	
		5.765	153	152 (5.76 GHz)		*		*
		5.785	157		√			*
		5.805	161	160 (5.80 GHz)		*	√	
	§15.247	5.825	165		√			

P802.11-REVma-D6.0

Regulatory class	Channel starting frequency (GHz)	Channel spacing (MHz)	Channel set	Transmit power limit (mW)	Emissions limits set	Behavior limits set
1	5	20	36, 40, 44, 48	40	1	1, 2
2	5	20	52, 56, 60, 64	200	1	1
3	5	20	149, 153, 157, 161	800	1	1
4	5	20	100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140	200	1	1
5	5	20	165	1000	4	1
6	4.9375	5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	25	5	9
7	4.9375	5	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	500	5	9
8	4.89	10	11, 13, 15, 17, 19	50	5	9
9	4.89	10	11, 13, 15, 17, 19	1000	5	9
10	4.85	20	21, 25	100	5	9
11	4.85	20	21, 25	2000	5	9
612–255	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

Part 90Y Test Channels

Mode	GHz	Channel No.	Channel BW (MHz)	Default/Required Test Channels
Part 90 Subpart Y	4.9425	1	5	√
	4.9475	2		
	4.9525	3		
	4.9575	4		
	4.9625	5		√√
	4.9675	6		
	4.9725	7		
	4.9775	8		
	4.9825	9		
	4.9875	10		√
	4.945	11	10	√
	4.955	13		
	4.965	15		√
	4.975	17		
	4.985	19		√
	4.955	21	20	√
	4.975	25		√

Antenna Diversity

- receive diversity only
  - identify and test dedicated transmit antenna
- legacy switched diversity
  - test and determine highest SAR antenna
    - complete tests using antenna with highest SAR
    - test both antennas if SAR > 1.2 W/kg & > 25% variation
  - apply defined duty factor
- spatial diversity MIMO & cyclic delay diversity
  - simultaneous transmission
- 2-antenna beam-forming
  - simultaneous transmission + maximum EIRP condition
- other diversity configurations: contact FCC
  - STC, phased array, n-antenna beam-forming etc.

TCB Approval

- devices should be tested according to these procedures to qualify for TCB approval
  - SAR Measurement Procedures for 3G Devices
    - CDMA 2000 / Ev-Do
    - WCDMA / HSDPA
  - SAR Measurement Requirements for 3 – 6 GHz
  - SAR Measurement Procedures for 802.11 a/b/g Transmitters
- otherwise, contact the FCC to determine if
  - exceptions can be made
  - additional procedures and/or requirements may apply
  - application should be submitted to the FCC for approval